Surface Atmosphere Radiation Budget (SARB) working group update

Seiji Kato[1], Fred G. Rose[2], David A. Rutan[2],
Alexander Radkevich[2], Seung Hee Ham[2], Tyler J. Thorsen[1]
Thomas E. Caldwell[2], Antonio Viudez-Mora[2], Ryan C. Scott[2],
David Fillmore[3], and Xianglei Huang[4]

[1]NASA Langley Research Center

[2]Science System & Applications Inc.

[3]NCAR

[4]University of Michigan

CERES Science Team Meeting
October 12-14, 2021

Outline of this presentation

- Sea ice map
- Total area (cloud removed) clear-sky correction
- Update Surface Validation Files to NetCDF
- Aerosol optical thickness in Edition 4.1 SYN1deg

Ice and snow map

- Ice age information is extracted from NOAA Comprehensive Large Array-Data Stewardship System (CLASS) Defense Meteorological Satellite Program (DMSF) data
- Ice age information is used to determine the spectral shape of ice albedo

Sea ice albedo with different ice ages

Multi-year white ice

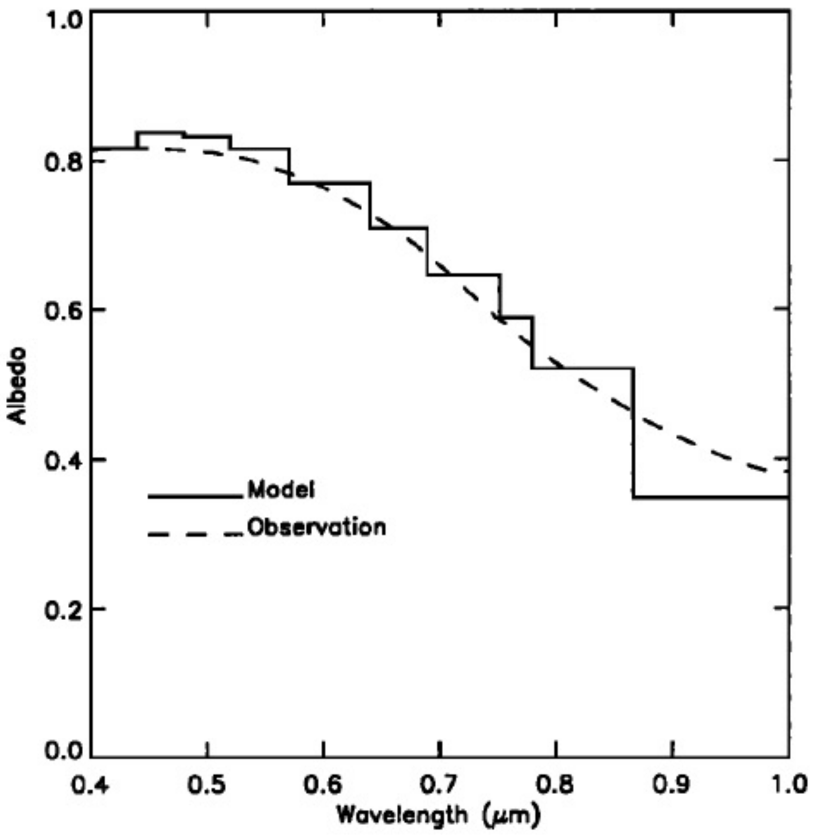


Figure 6. Comparison of observed spectral albedo for melting multiyear white ice with model calculations. Observations are from *Grenfell and Maykut* [1977].

First year blue ice

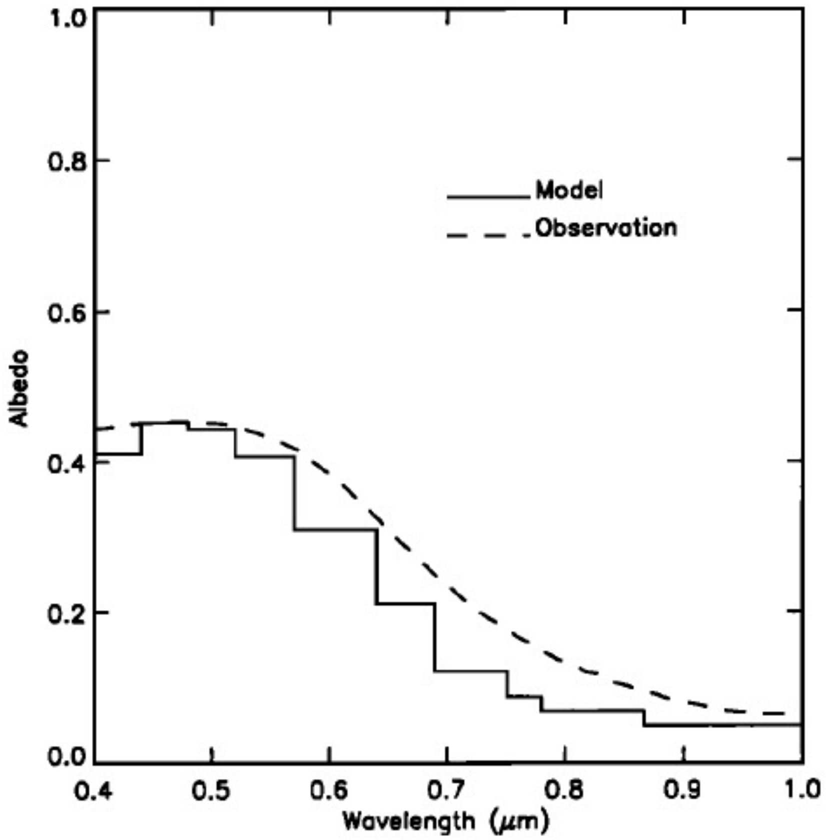


Figure 7. As in Figure 6, but for melting first-year blue ice.

Because sea ice (surface) broadband albedo is derived from clear-sky CERES scenes, ice age determines spectral shape of albedo.

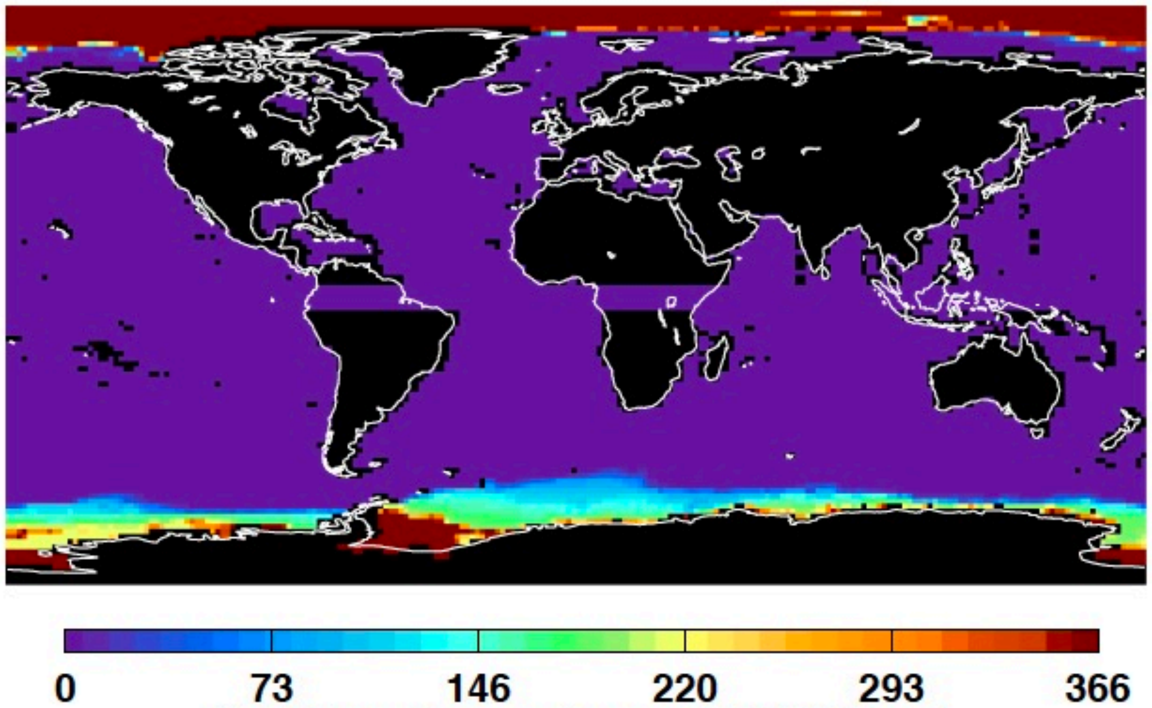
Spectral differences lead to a ~10 Wm-2 surface upward shortwave difference

Jin et al. 1994

Current issues

- CLASS DMSP gridded data product (i.e. sea ice age) is no longer available from August 2021 onward.
  - Production of the swath product in near future is uncertain
- Given the sensitivity of sea ice albedo, switching ice age data source is preferable compared to dropping ice age information.
- Another source of ice age information in CERES input data
  - Air Force Weather Agency (AFWA) sea ice product
  - Our plan is to use the AFWA product from August 2021 onward.

Ice age derived from AFWA data product



AFWA sea ice age for sep30 2021(days)

N= 40254 Glb mean(sd): * 11.68 (110.7) Mn/Mx: 0.0/ 365.0

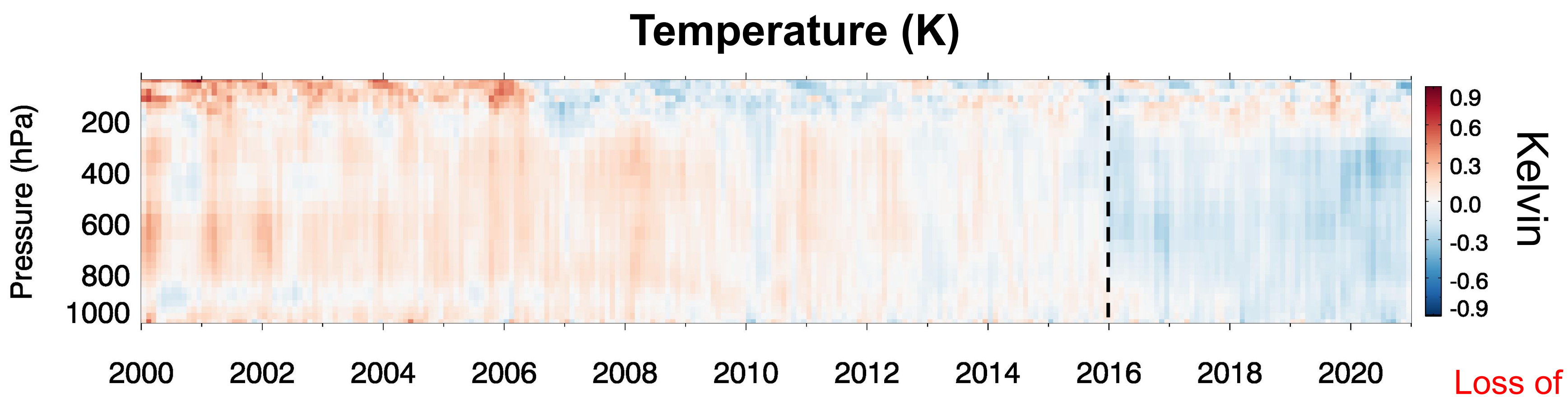
Recent activities

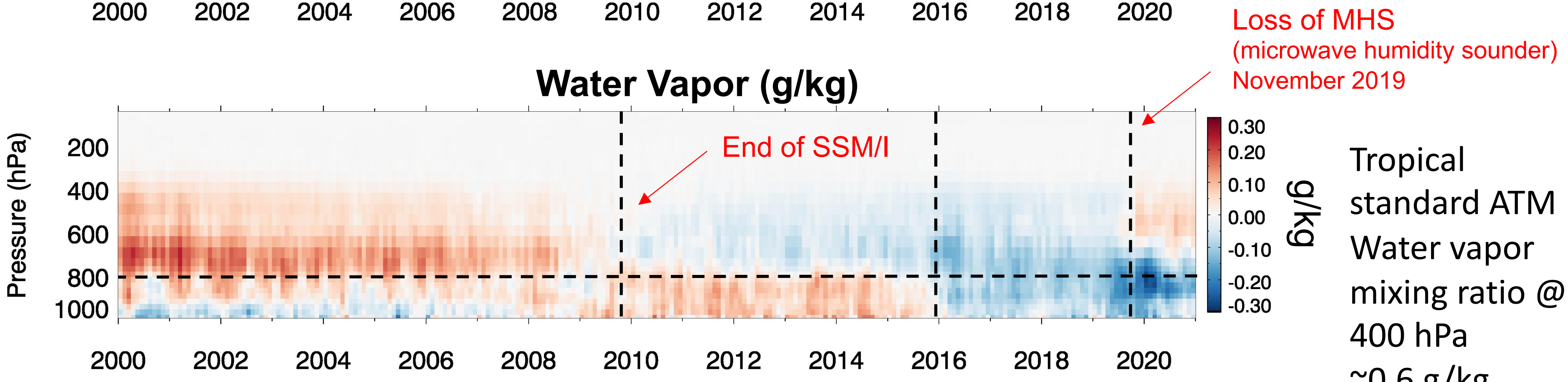
- EBAF (surface) product is extended through June 2021
  - Total area clear-sky correction with MERRA-2 was applied from data month of November 2019 onward.
- Evaluated Edition 4 MATCH aerosol optical thickness
  - Manuscript was submitted to ACP and revised in October.
- Started working on Edition 5 MATCH
  - CAM 6 runs on AMI
- Produced CCCM D1 version (Ham's presentation)
  - Uses Edition 4 ADM, Edition 5-beta cloud algorithm, Version 4 CALIPSO, and R05 CloudSat data products.
  - D1 version will be available to public soon.
- Developed a framework of using averaged spectral radiances to correct temperature and humidity profiles used in flux computations
- Started updating binary files and codes used for surface flux validations.
- Developed a plan for EBAF (Edition 4.2) to be processed after Terra/Aqua mean local time drifts
  - Edition 4.2 avoids influence of GEO artifacts to surface flux anomalies.

Total area clear-sky (cloud removed) flux correction

Area weighted; climatology is obtained using 2003-2020

[G-5.4.1 Anomalies] – [ERA-5 Anomalies]

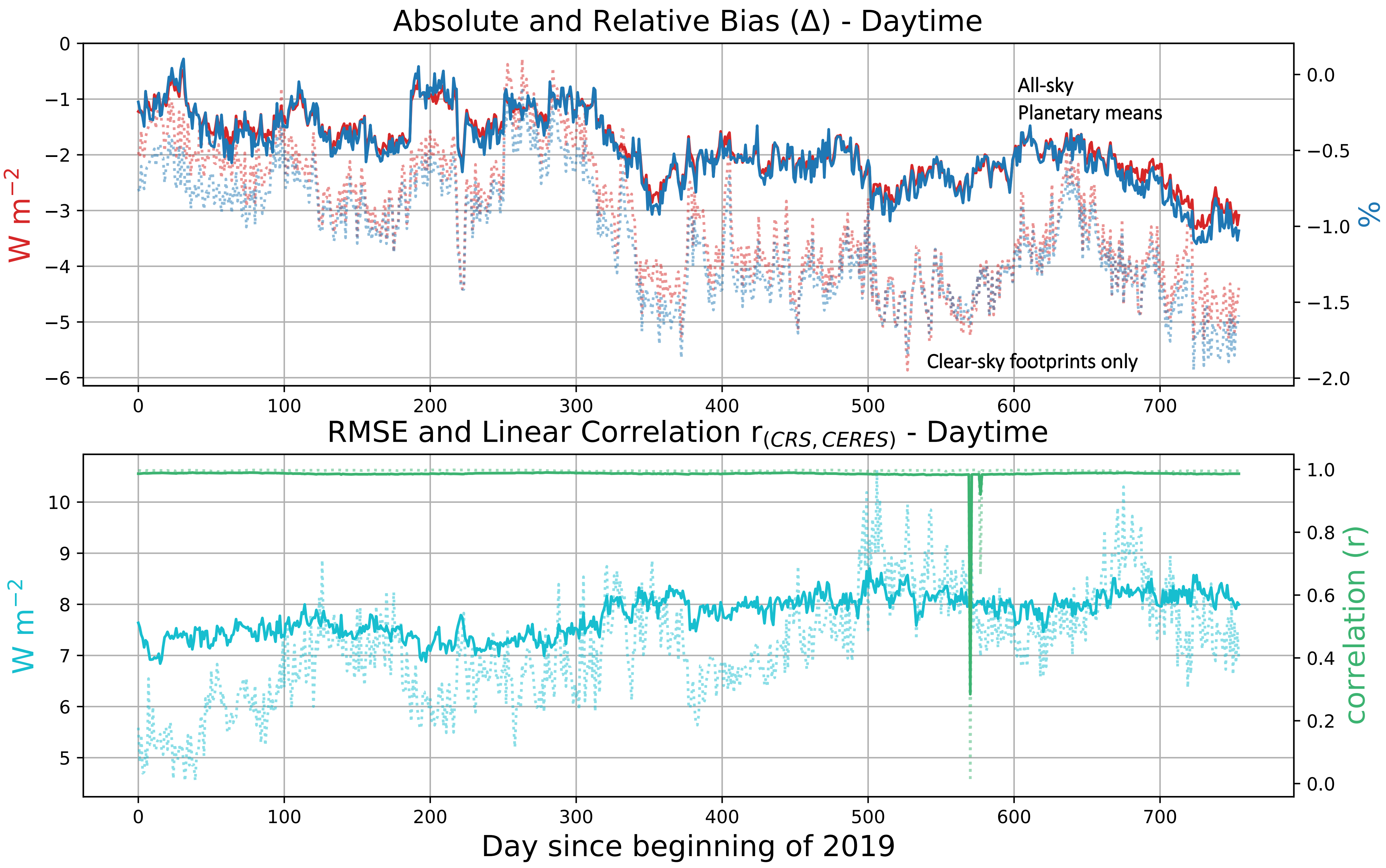




Tropical standard ATM Water vapor mixing ratio @ 400 hPa ~0.6 g/kg ~20 to 30% drift

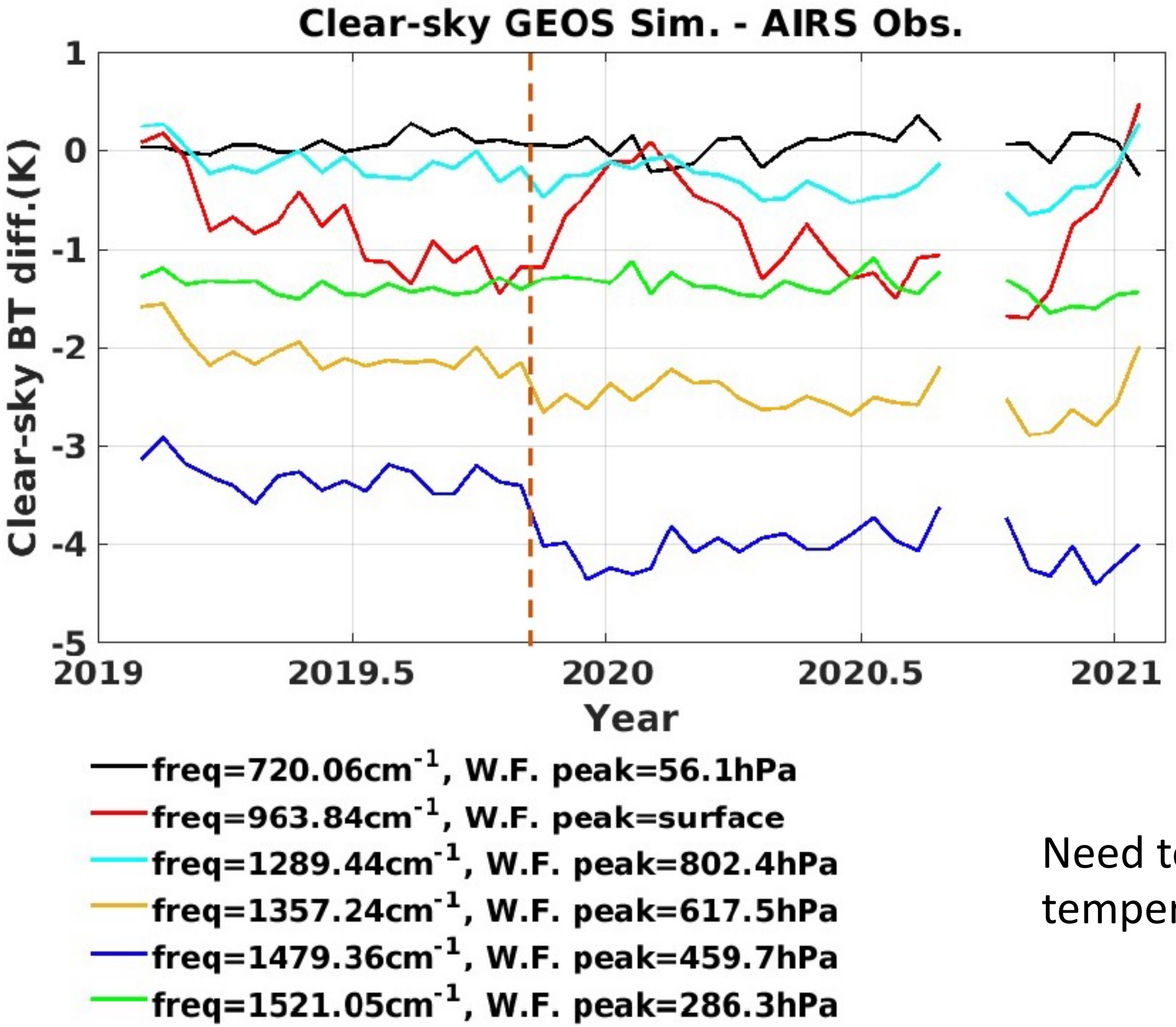
- The differences between G541 and ERA5 are similar to those between G541 and MERRA-2.
- This implies that the differences are mainly driven by G541 problems.

Terra FM1 CRS OLR TOA Validation Statistics



Forward model: Spectral radiance

Time series of 16-day and global-mean clear-sky BT diff.



Using clear-sky AIRS Obs. collocated with CERES, VZA<5°

There is no AIRS data during Aug17-Sep2, 2020

Need to convert the spectral radiance difference to temperature and humidity differences

Total area clear-sky flux correction approach

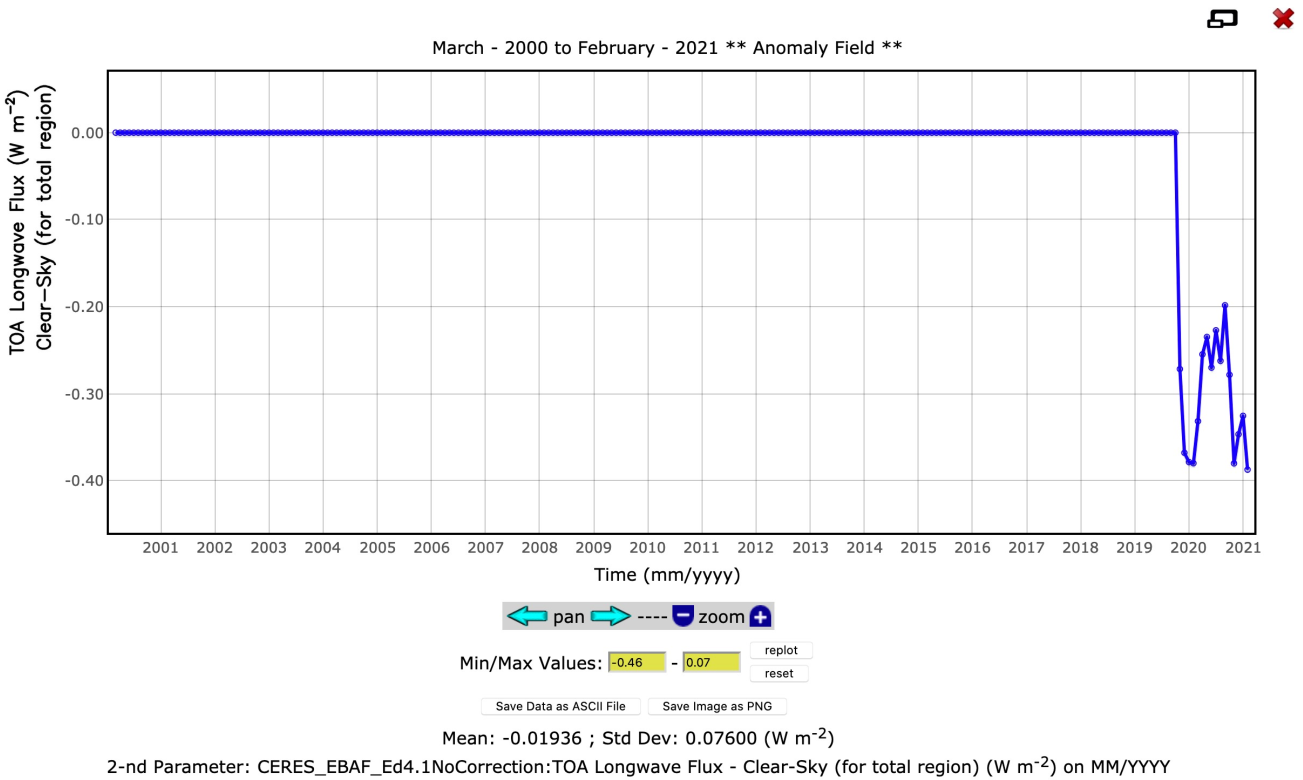
- Total area (cloud removed) clear-sky TOA and surface flux is derived by applying sampling correction (Loeb et al. 2019). $\Delta^{c}_{new} = F(cldRem) - F(Obs.wgt)$
- Compute total area and clear-sky fraction weighted temperature and specific humidity using MERRA-2 and GEOS-5.4.1.
- Derive $\Delta^{c}_{correction}$ using MERRA-2 and GEOS-5.4.1 cloud removed obs. weight temperature and humidity differences.
    - This is done using TOA LW up and surface LW down radiative kernel of temperature and specific humidity (no correction due to skin temperature difference).
- Add the correction to F(g541,cldrem) and F(g541,obs. weight).

$$\Delta^{c}_{new} = \Delta^{c}_{G541} + \Delta^{c}_{correction}$$

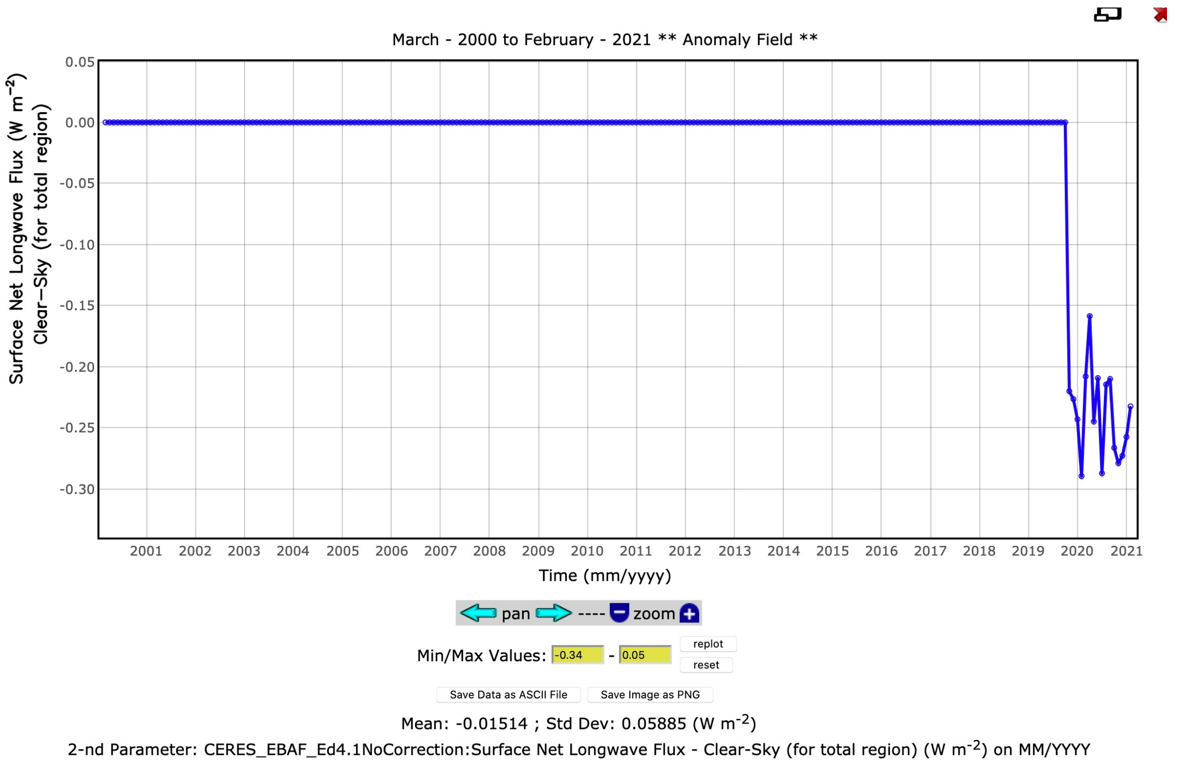
- The correction is applied regionally.

TOA up LW and surface net LW anomalies Corrected – no correction

TOA



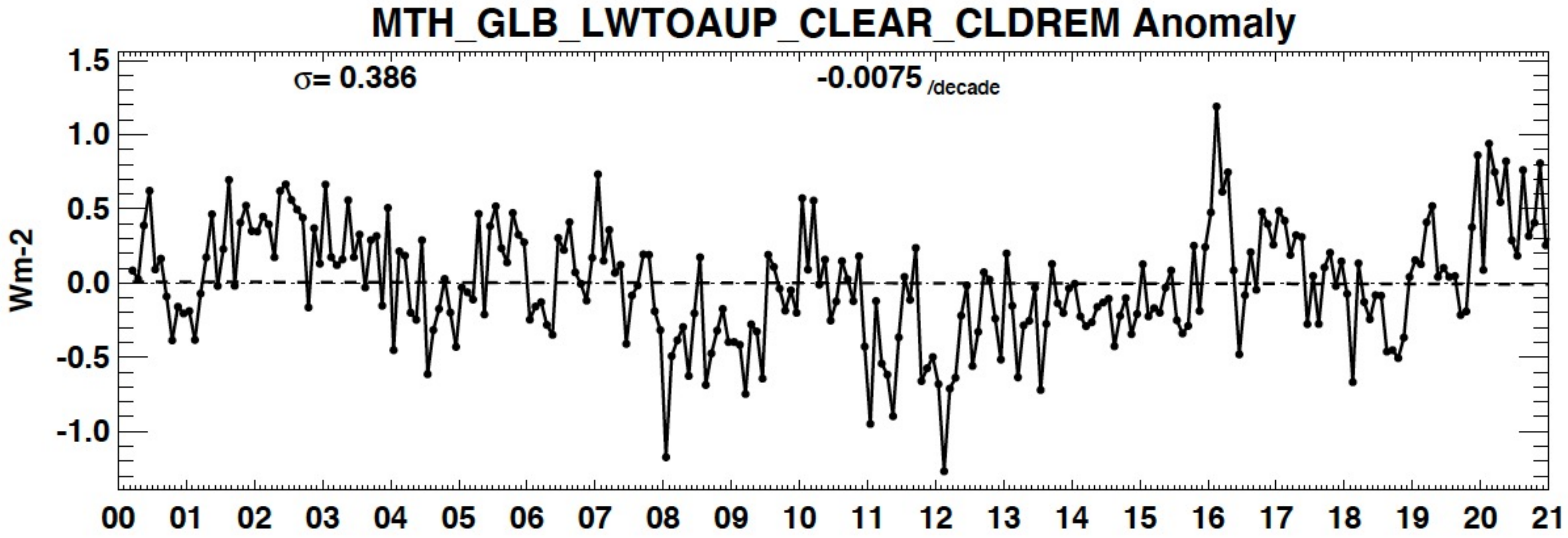
Surface



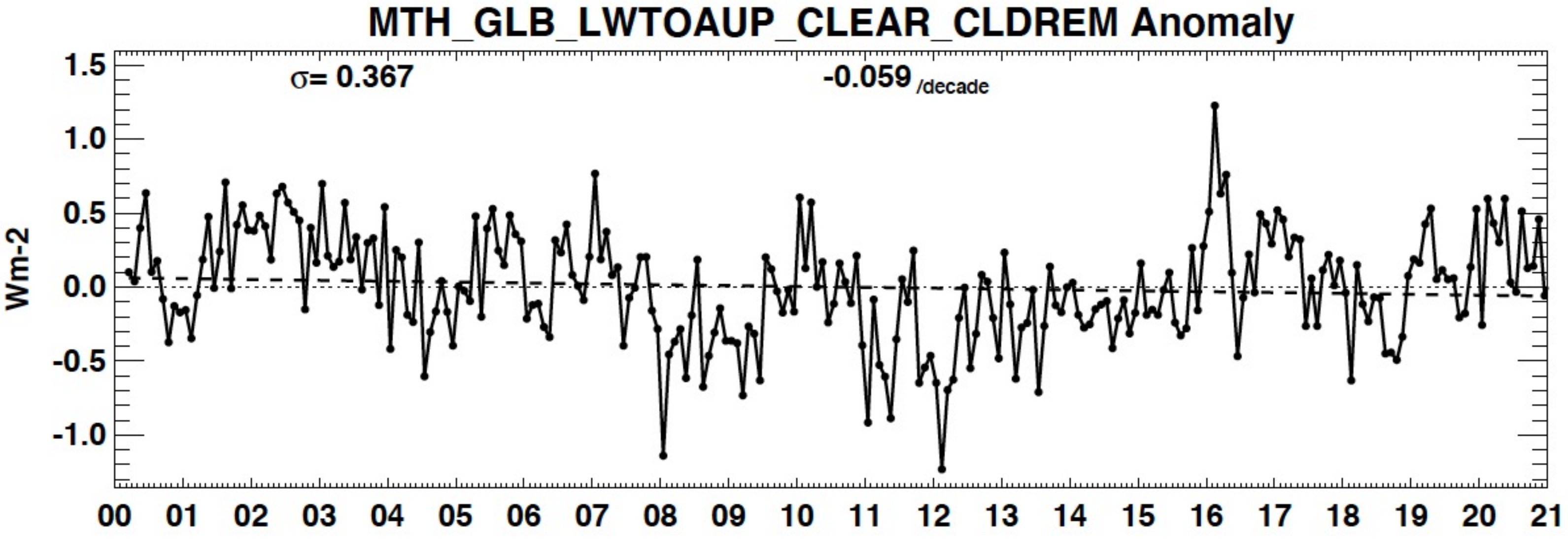
Although it is small, the correction adds discontinuity.

Total area clear-sky OLR anomalies

No correction
i.e. using Δ^{c}_{G541}

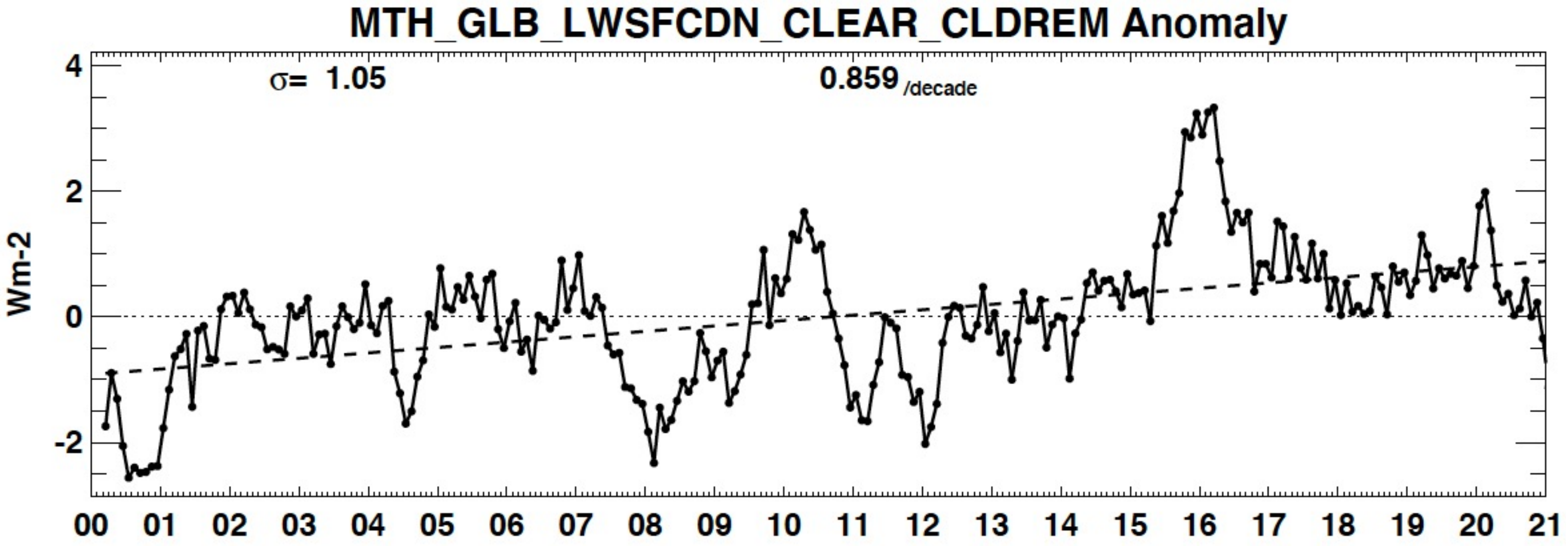


With correction
i.e. using Δ^{c}_{new}

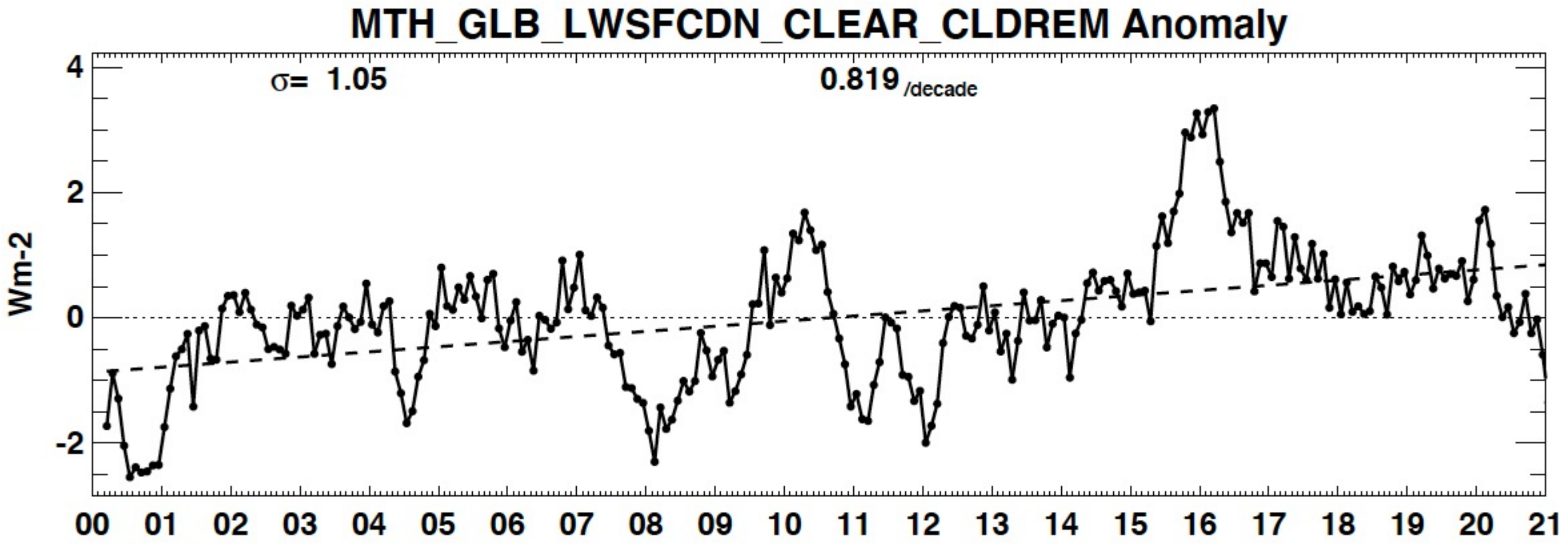


Total area clear-sky surface downward longwave anomalies

No correction



With correction



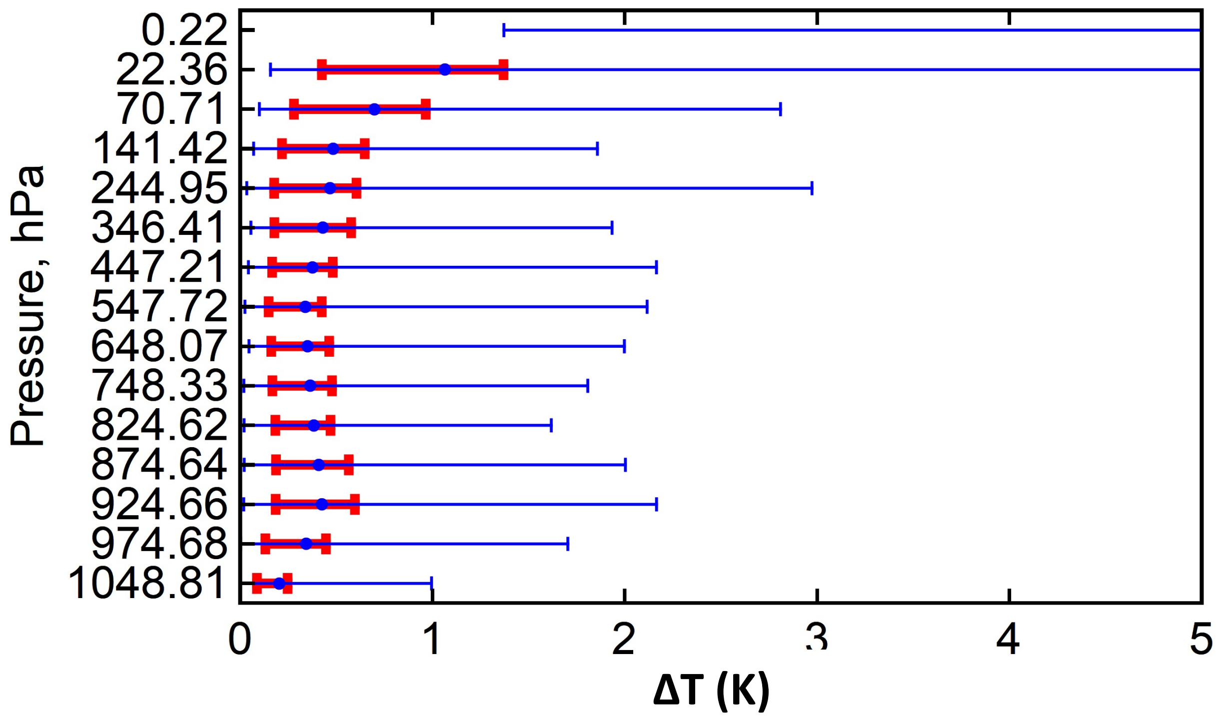
Approach of converting spectral radiance difference to temperature and specific humidity differences

- Computed spectral radiance – observed (AIRS) spectral radiance: $\Delta\mathbf{R}$
- Spectral radiative kernels $\overline{\mathbf{K}^*}$
- Error covariance matrix $\mathbf{S}_\mathrm{R}$: Covariance of spectral variability
- A priori information covariance matrix $\mathbf{S}_\mathrm{a}$: covariance of $\Delta\mathbf{a}_p$
- Smoothing covariance matrix $\mathbf{S}_\mathrm{G}$
- A priori information $\overline{\Delta\mathbf{a}_p}$: difference of reanalysis and AIRS Level 3 temperature and specific humidity profile

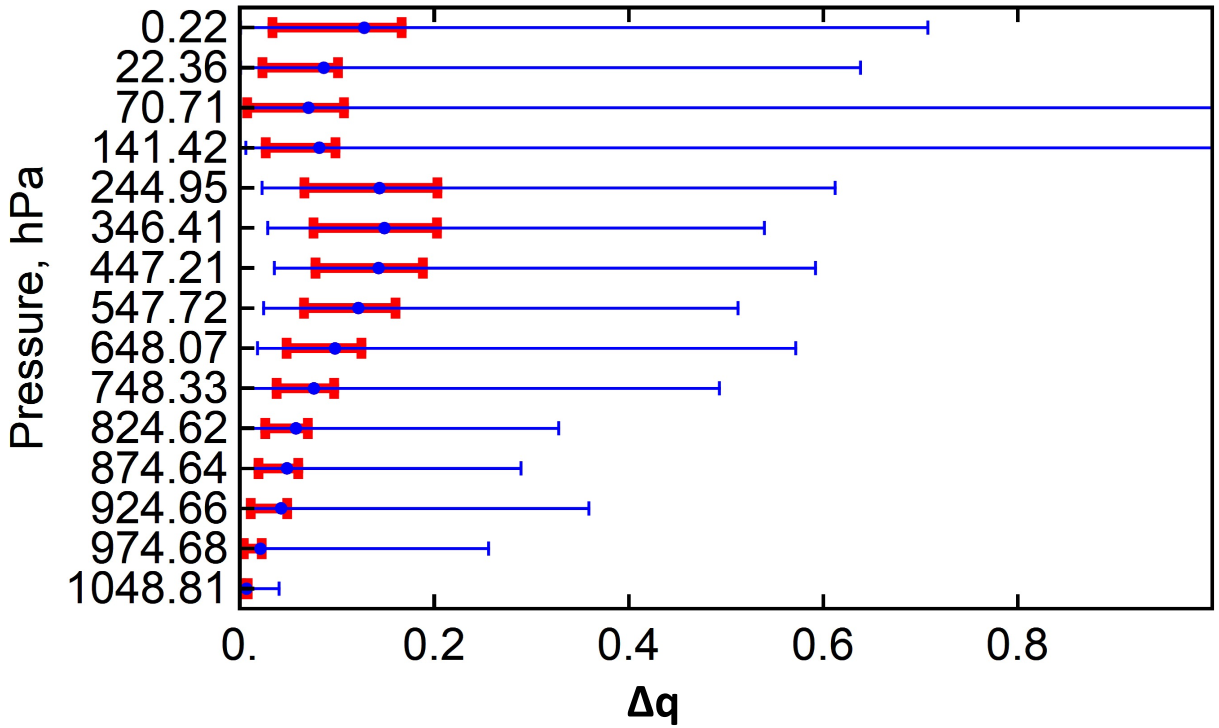
$$\overline{\Delta\mathbf{a}}^* = \left(\overline{\mathbf{K}}^{*\mathrm{T}}\mathbf{S}_\mathbf{R}^{-1}\overline{\mathbf{K}}^* + \mathbf{S}_\mathbf{a}^{-1} + \mathbf{G}^\mathrm{T}\mathbf{S}_\mathbf{G}^{-1}\mathbf{G}\right)^{-1} \times \left(\overline{\mathbf{K}}^{*\mathrm{T}}\mathbf{S}_\mathbf{R}^{-1}\Delta\overline{R} + \mathbf{S}_\mathbf{a}^{-1}\overline{\Delta\mathbf{a}}_p + \mathbf{G}^\mathrm{T}\mathbf{S}_\mathbf{G}^{-1}\mathbf{G}\overline{\Delta\mathbf{a}}_p\right),$$

Conversion of spectral difference to T and q difference
A priori = difference of reanalysis and AIRS Level 3 values

ΔT = |retrieved ΔT – a priori ΔT|



Relative Δq =
|(retrieved relative Δq – a priori relative Δq)|



Blue dots indicate the mean, rad error bars indicate 50% populations, and blue error bars indicate entire populations.

These are derived from observed and computed 16-day mean spectral radiance differences over the 10 deg by 10 deg grid boxes globally.

Update Surface Validation Files to NetCDF

- Generate Python code to convert binary surface observation data to NETCDF.

- Files will contain all available data from:
  - ARM, BSRN, SURFRAD, NOAA GMD, WHOI and PMEL buoys.
  - All files will include measurements of radiation, meteorology, solar zenith angle.
  - Others include MWR, ceilometer and AERONET (or MFRSR) AOD’s if available.

- Each file will contain multiple time resolutions, organized into NetCDF groups:
  - 1-minute data (If available)
  - Hourly means
  - Daily means
  - Monthly means

Aerosol optical thickness in Edition 4.1 SYN1deg

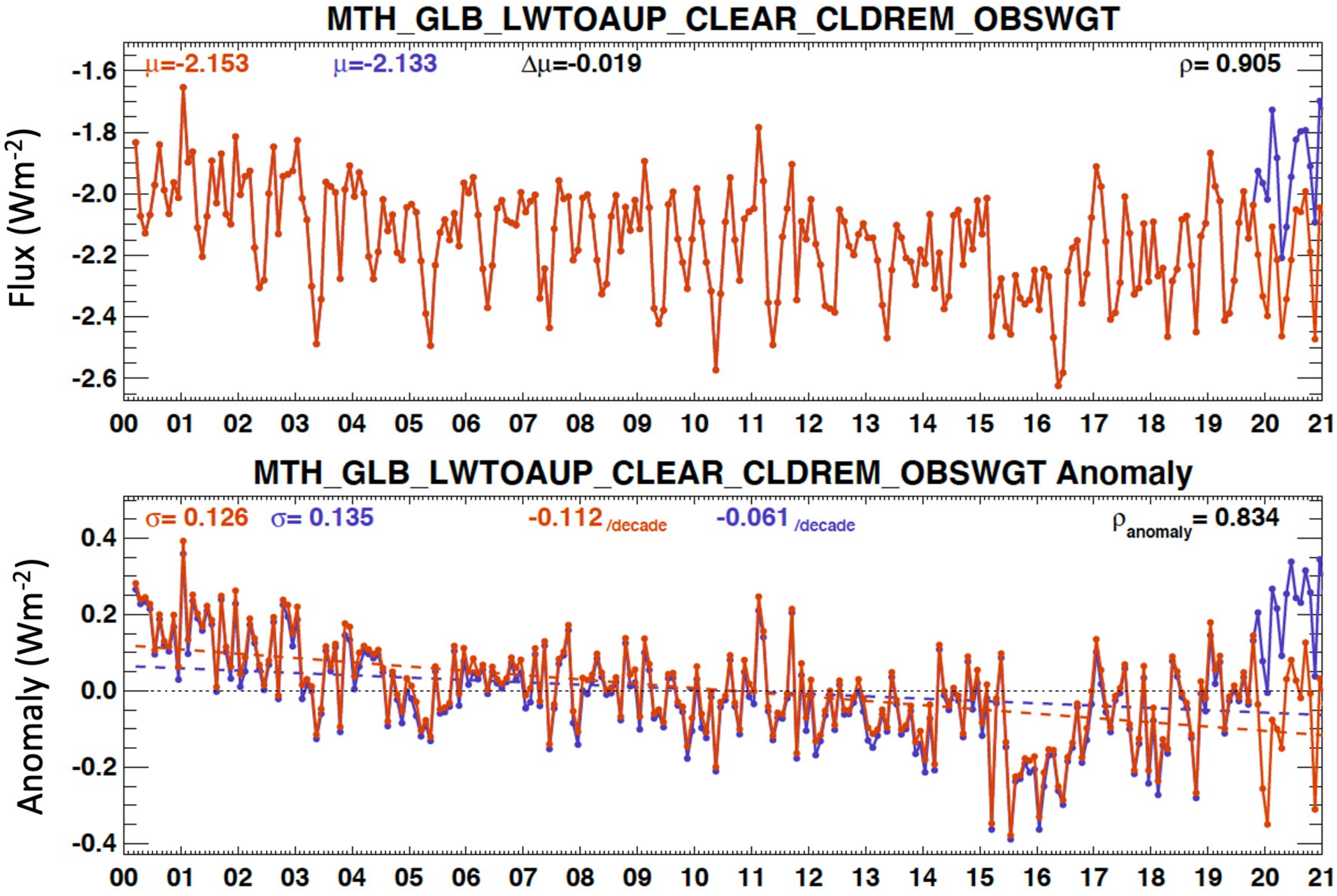
- Dark target and Deep blue aerosol optical thickness derived from Terra and Aqua are combined to form daily aerosol optical thickness maps.
- **Only Terra AOT was used from July 2002 through December 2002**
- This is because of missing geolocation information but having an optical thickness
    - /ASDC_archive/MODIS/Terra/C61/2004/186/MOD04_L2.A2004186.0745.061.2017286135800.hdf, at location 8497 OR (127,63) has “DEEP_BLUE_AEROSOL_OPTICAL_DEPTH_550_LAND” has a non default value of 38 but -999 in the latitude and longitude slots. The swath dimension is [135,204]
- Similarly, **only Aqua AOT was used from July 2004 through December 2004** due to the same default value problem.
    - /ASDC_archive/MODIS/Aqua/C61/2002/195/MYD04_L2.A2002195.0955.061.2017363021249.hdf, at location 26818 or(88, 199) DEEP_BLUE_AEROSOL_OPTICAL_DEPTH_550_LAND” has non default value of 221 with -999 for lat and lon. The swath dimension is [135, 203].

Publications

- Ham, S.-H., S. Kato, F. G. Rose, N. G. Loeb, K.-M. Xu, T. Thorsen, M. G. Bosilovich, S. Sun-Mack, Y. Chen, and W. F. Miller, 2021: Examining Cloud Macrophysical Changes over the Pacific for 2007–17 Using CALIPSO, CloudSat, and MODIS Observations, *J. Appl. Meteo. Clim*., 60(8), 1105-1126.
- Fillmore, D. W., D. A. Rutan, S. Kato, F. G. Rose, and T. E. Caldwell, 2021: Evaluation of aerosol optical depths and clear-sky radiative fluxes of the CERES Edition 4.1 SYN1deg data product, submitted to *Atmospheric Chemistry and Physics*.
- Kato S, Rose FG, Chang F-L, Painemal D and Smith WL (2021) Evaluation of Regional Surface Energy Budget Over Ocean Derived From Satellites. *Front. Mar. Sci*. 8:688299. doi:10.3389/fmars.2021.688299

Back-ups

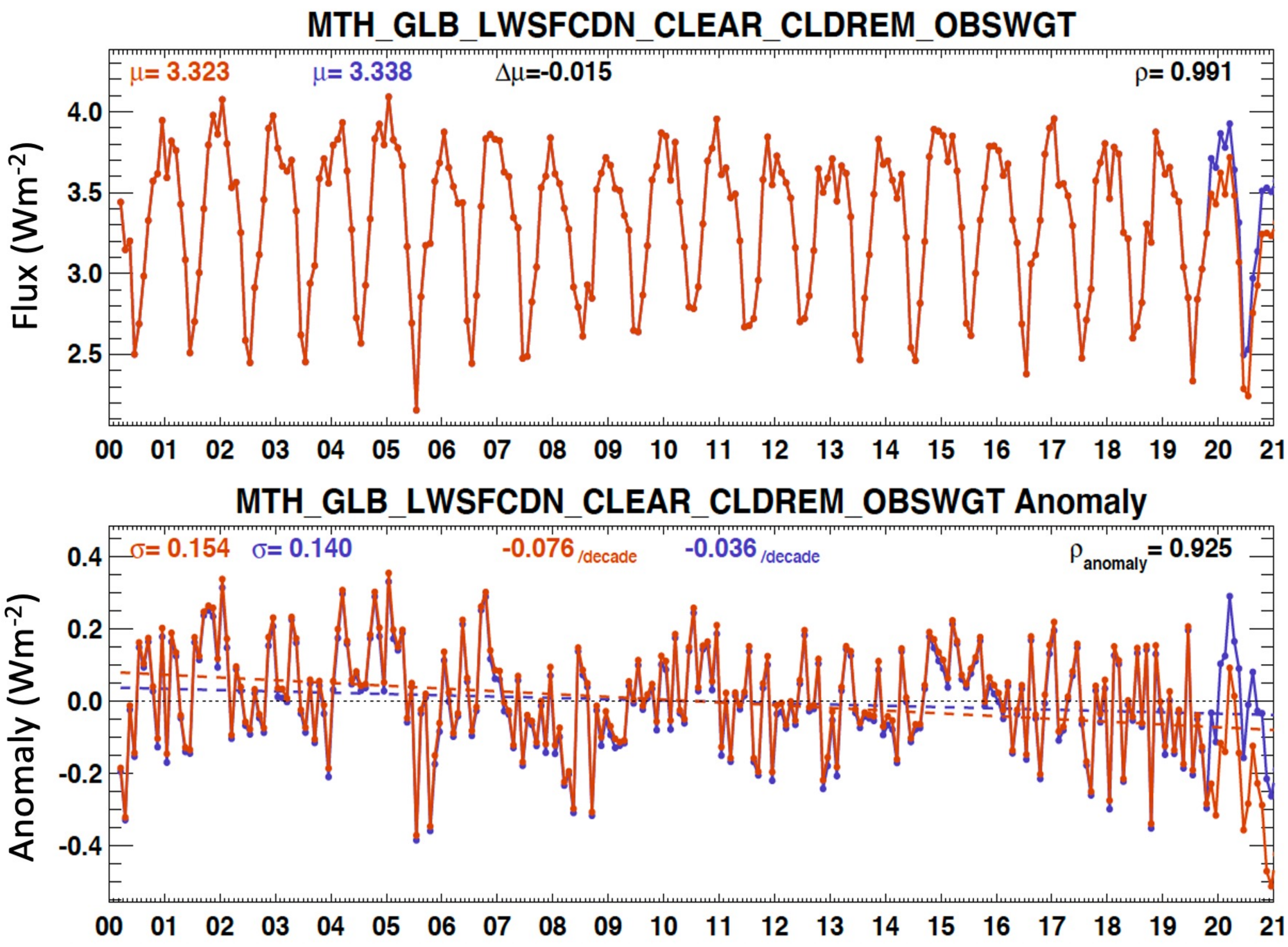
TOA clear-sky OLR Δ^c timeseries



Blue: Δ^c_{G541}

Red: Δ^c_{new}

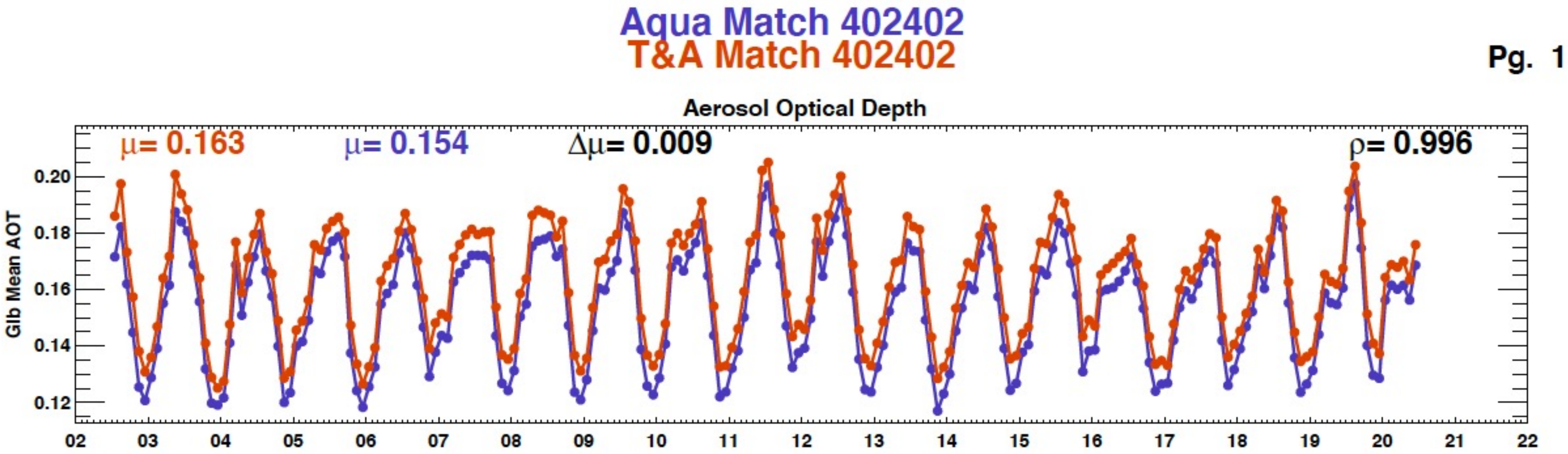
Total area clear-sky surface downward longwave Δ^c

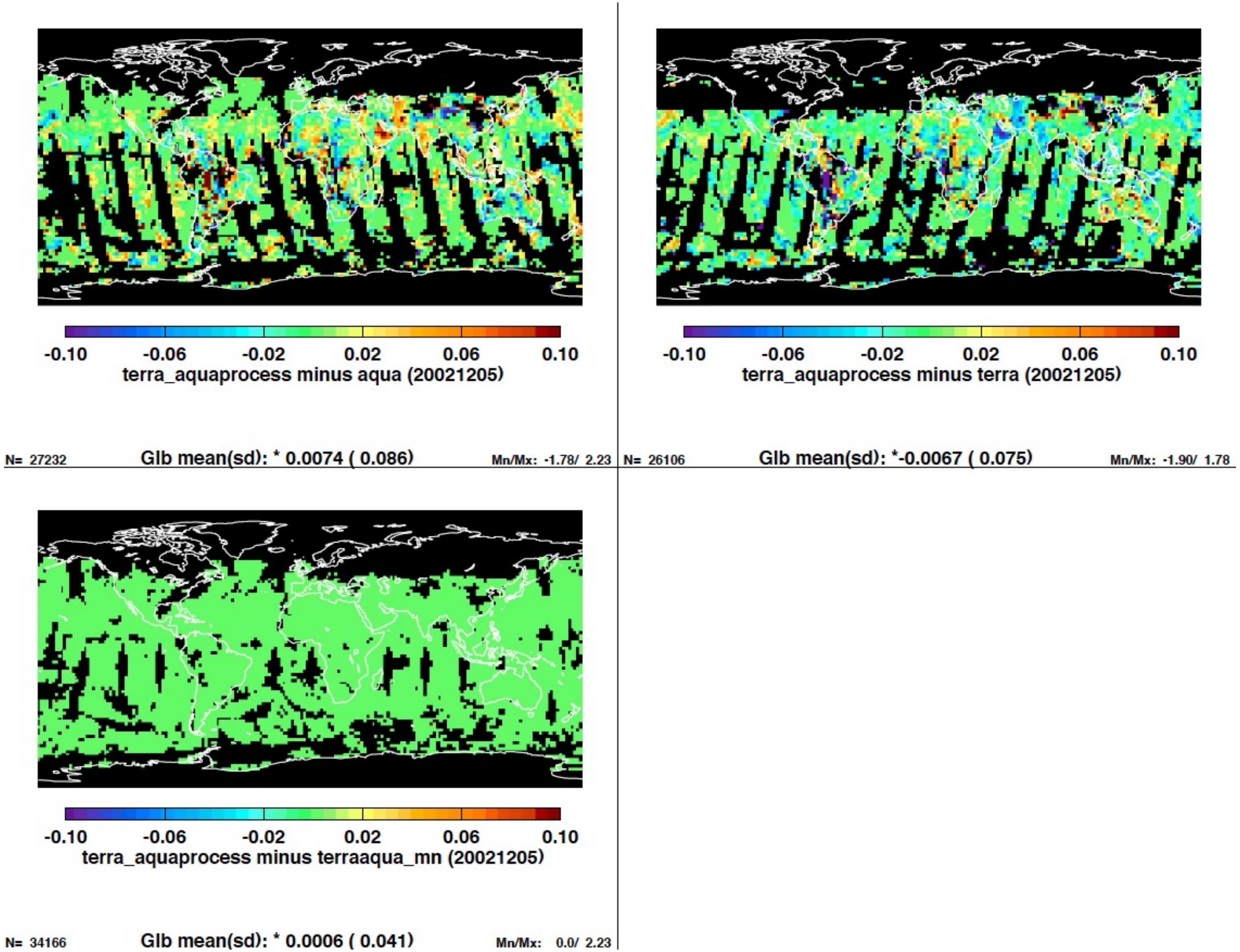


Blue: Δ^c_{G541}

Red: Δ^c_{new}

MATCH


Aqua Match 402402
T&A Match 402402
Pg. 1
Aerosol Optical Depth
μ= 0.163
μ= 0.154
Δμ= 0.009
ρ= 0.996
Glb Mean AOT
0.20
0.18
0.16
0.14
0.12
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22


-0.10 -0.06 -0.02 0.02 0.06 0.10
terra_aquaprocess minus aqua (20021205)
N= 27232
Glb mean(sd): * 0.0074 (0.086)
Mn/Mx: -1.78/ 2.23
-0.10 -0.06 -0.02 0.02 0.06 0.10
terra_aquaprocess minus terra (20021205)
N= 26106
Glb mean(sd): *-0.0067 (0.075)
Mn/Mx: -1.90/ 1.78
-0.10 -0.06 -0.02 0.02 0.06 0.10
terra_aquaprocess minus terraaqua_mn (20021205)
N= 34166
Glb mean(sd): * 0.0006 (0.041)
Mn/Mx: 0.0/ 2.23

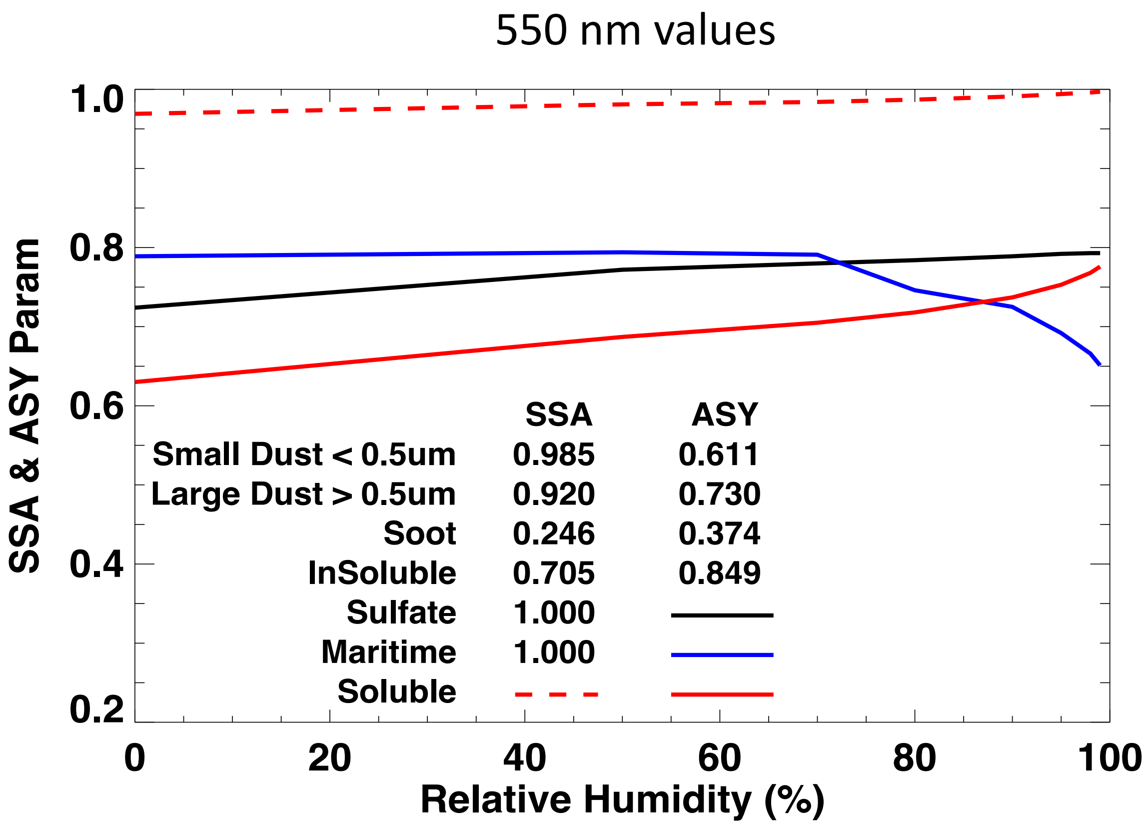
Terra only and Aqua only MATCH vs. Terra+Aqua MATCH

Edition 4 MATCH

Table 1. Aerosol Types & Climatological Sources		
Aerosol Type	Source	Description
Sea Salt	Blanchard and Woodcock, 1980	Wind Driven
Dust	Ginoux et al. (2001); Zender et al. (2003)	NCEP soil moisture, wind driven
Sulfate (natural & anthropogenic)	Benkovitz et al. (1996); Barth et al. (2000)	monthly climatological
Carbon (organic & Soot)	Liousse et al. (1996)	monthly climatological
Volcanic	Episodic inclusion of Sulfur dioxide	Processed by model

Aerosol optical property

Edition 4



Edition 5: Optical property depends on time and space

Time dependent source function

Need some descriptions about what MATCH does

Fillmore et al. 2021

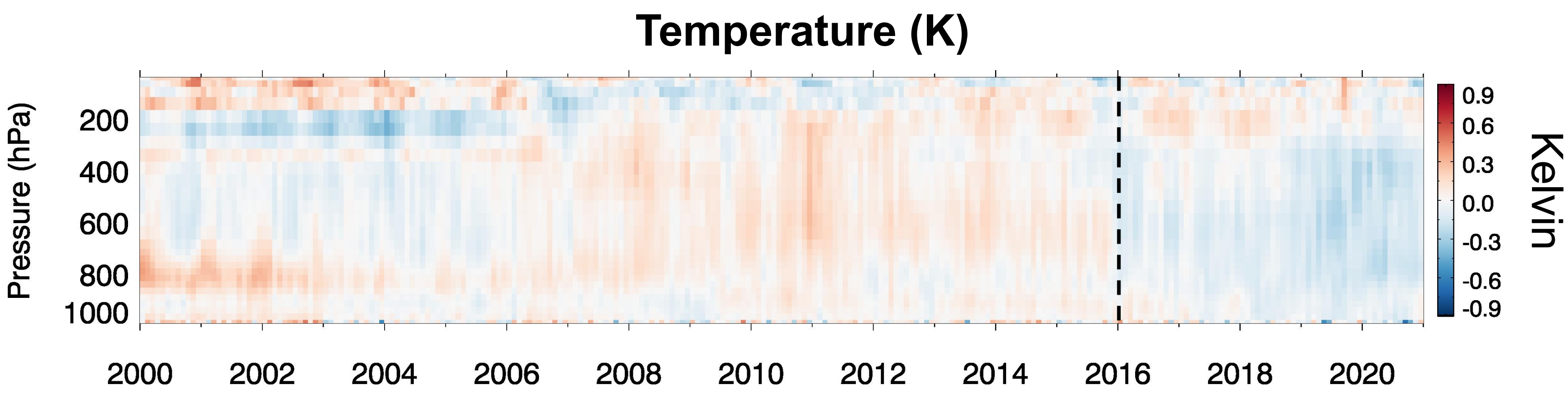
EBAF/SYN related work

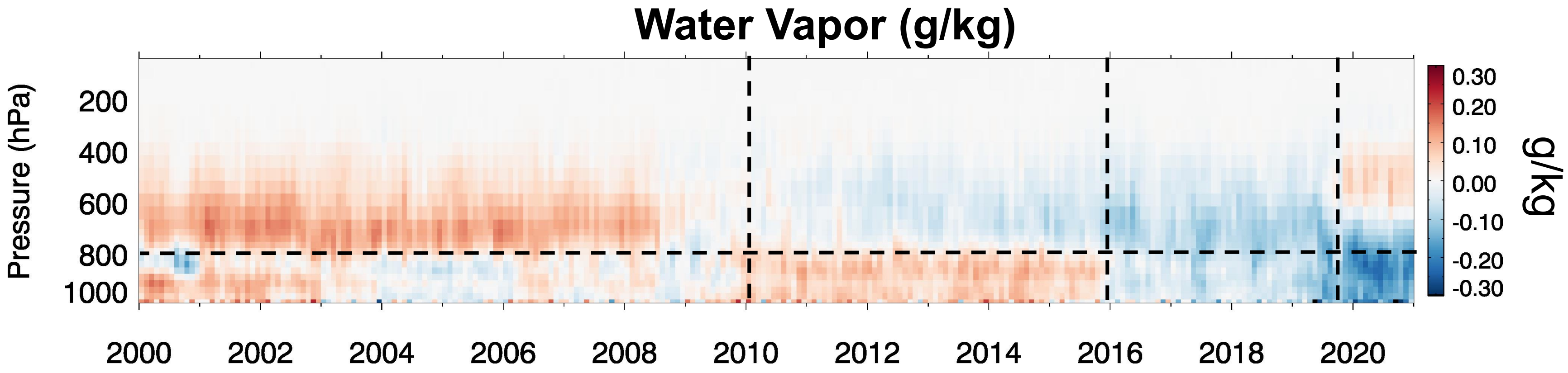
- Produced Aqua+GEO and Aqua only SYN to test no GEOs in surface irradiance anomaly timeseries
- Produced MERRA-2 MOA to be used for a sensitivity study to understand surface irradiance sensitivity to different reanalysis products.
- Sensitivity study of using different reanalysis products (April 2019)
  - Clouds produced with GEOS-541 and SARB run with MERRA-2
  - Both clouds and SARB run with MERRA-2 to be compared with Edition 4 SYN and CRS.

60S-60N Land+Ocean

Area weighted; climatology is obtained using 2003-2020

[G-5.4.1 Anomalies] – [MERRA-2 Anomalies]





- Compared to MERRA-2, G541 temperature anomalies larger before 2016 and smaller after 2016.
- The differences in WV anomalies flip signs across 800 hPa pressure level, also beginning of 2010, 2016, and 2020.